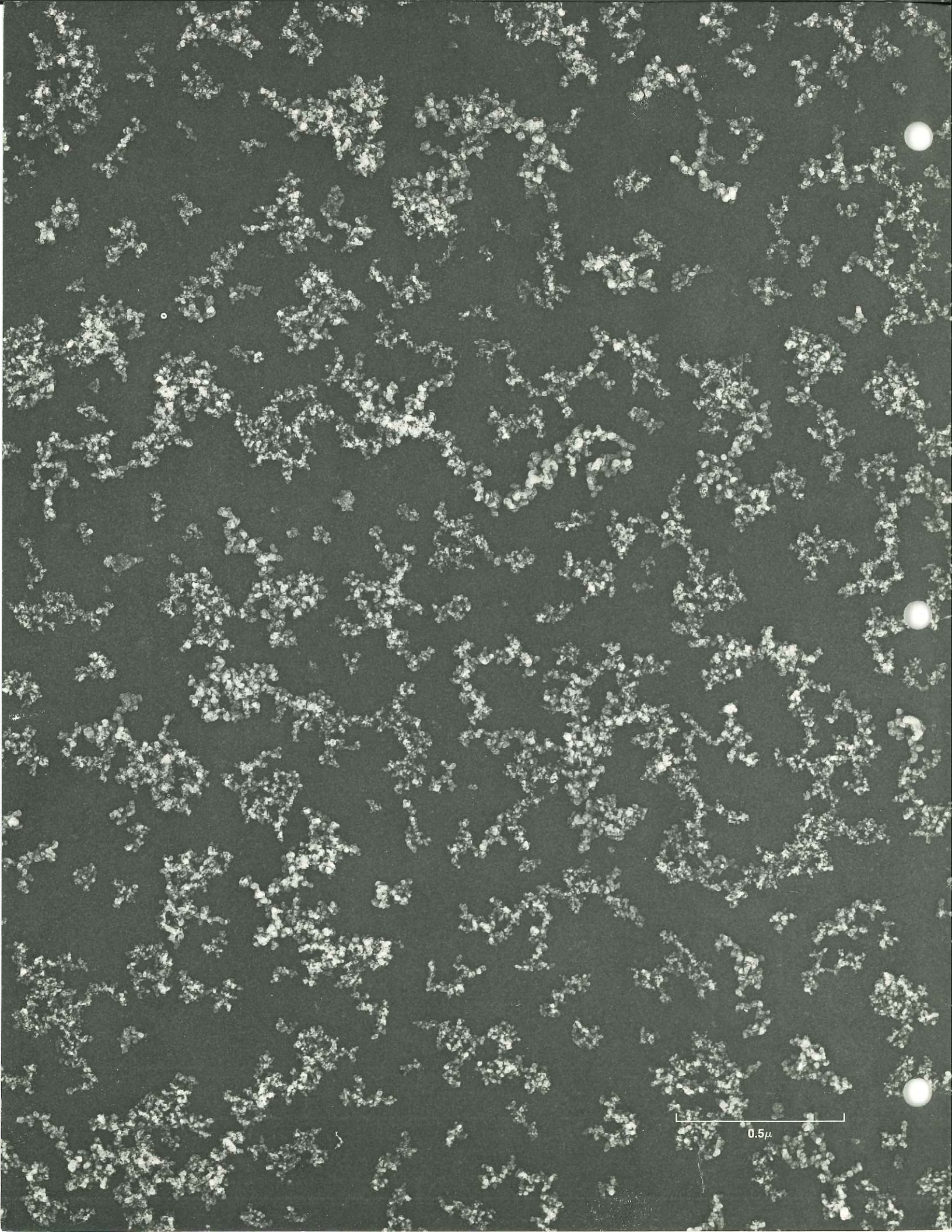
Cab-O-Sil® in coatings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Cab-O-Sil in coatings

Contents

Introduction	2
Properties	2
Cab-O-Sil's action in liquids	4
Flow control	4
Thickening	6
Thixotropy	6
Suspension	10
Gloss reduction	11
Free flow	11
Powder coatings	12
Multiple functions with Cab-O-Sil	13
Aerosols	13
Getting the most from Cab-O-Sil	14
Physiological data	14
Typical coatings formulas	16
Index	17

Left: Electron photomicrograph of Cab-O-Sil M-5 at a magnification of 80,000X (from a negative print). The chain-like aggregates consist of fused spherical primary particles of pure silica.

Cover: Glass rods dipped into a coating containing increasing concentrations of Cab-O-Sil illustrate the wide range of viscosities which can be achieved by the use of this unique flow control agent.

Introduction

Cab-O-Sil is a remarkable ingredient used to produce or control four major properties in protective coatings and paints:

1. Flow control, including thickening and thixotropy.
2. Suspension, or anti-settling.
3. Gloss reduction.
4. Free flow, anti-caking and fluidization of powders.

Cab-O-Sil is a fumed silica having particles of submicroscopic size with a total surface area of 200 to 400 square meters per gram, depending on grade. The combination of its unusually small particle size, tremendous surface area, purity and chain-forming tendencies makes Cab-O-Sil unique among silicas and unique among coatings additives as well.

Cab-O-Sil is effective in solvent, aqueous, pure-resin, and powder polymer systems. This brochure describes its use by the protective coatings industry, and gives some information to aid in obtaining optimum results from Cab-O-Sil. The researcher evaluating Cab-O-Sil should also refer to the Cab-O-Sil general brochure for additional data.

Properties of Cab-O-Sil

Cab-O-Sil is produced by hydrolysing pure silicon tetrachloride vapor in a flame of purified hydrogen and oxygen as shown in the reactions:

$$(1): 2H_2 + O_2 \longrightarrow 2H_2O$$
$$(2): SiCl_4 + 2H_2O \longrightarrow SiO_2\downarrow + 4HCl\uparrow$$

(Overall reaction):

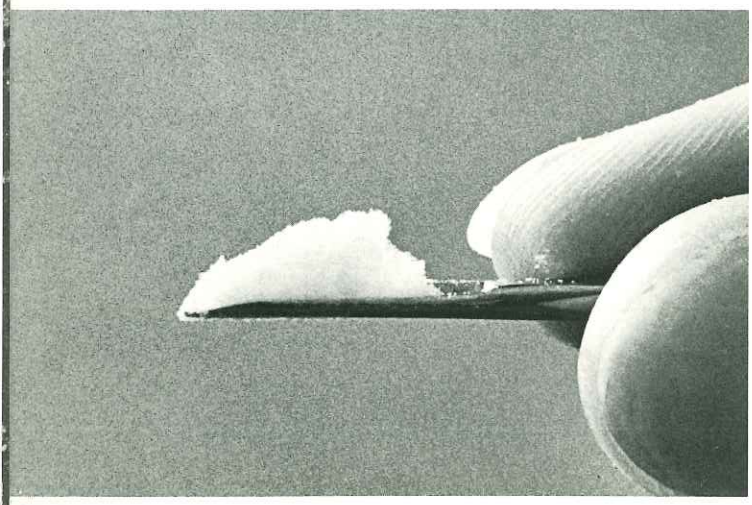
$$SiCl_4 + 2H_2 + O_2 \xrightarrow{1800^\circ\ C.} SiO_2\downarrow + 4HCl\uparrow$$

In the process, molten spheres of silica are formed first. They vary in average diameter from 7 to 14 millimicrons, depending on the grade.[1] These molten silica spheres, termed particles, collide and fuse with one another to form three-dimensional, branched-chain aggregates. Slight mechanical entanglement or agglomeration of these aggregates occurs later in the collection process. The residual adsorbed hydrogen chloride level on the Cab-O-Sil surface is then reduced by calcination to less than 0.02% by weight.

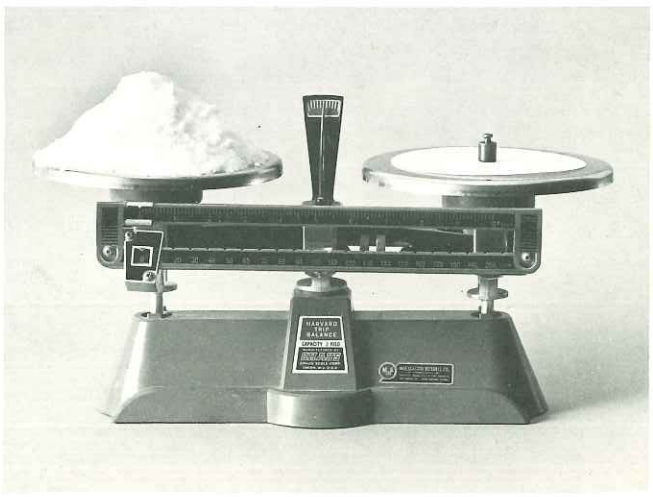
The resultant Cab-O-Sil is a very fine, non-porous, amorphous silica of large surface area and high purity. Cab-O-Sil is more than 99.8% silicon dioxide by weight (on a moisture-free basis) with almost no metallic impurities such as sodium, calcium and magnesium.

Hydroxyl groups attached to surface silicon atoms make the Cab-O-Sil surface hydrophilic, enhancing its ability to adsorb water and other polar liquids. More importantly, these surface hydroxyl groups allow hydrogen bonding to occur between neighboring Cab-O-Sil aggregates.

[1]*Calculated by assuming the particles are spherical and using the surface area as determined by the method of Brunauer, Emmet and Teller, J. Am. Chem. Soc., 60, 309 (1938).*

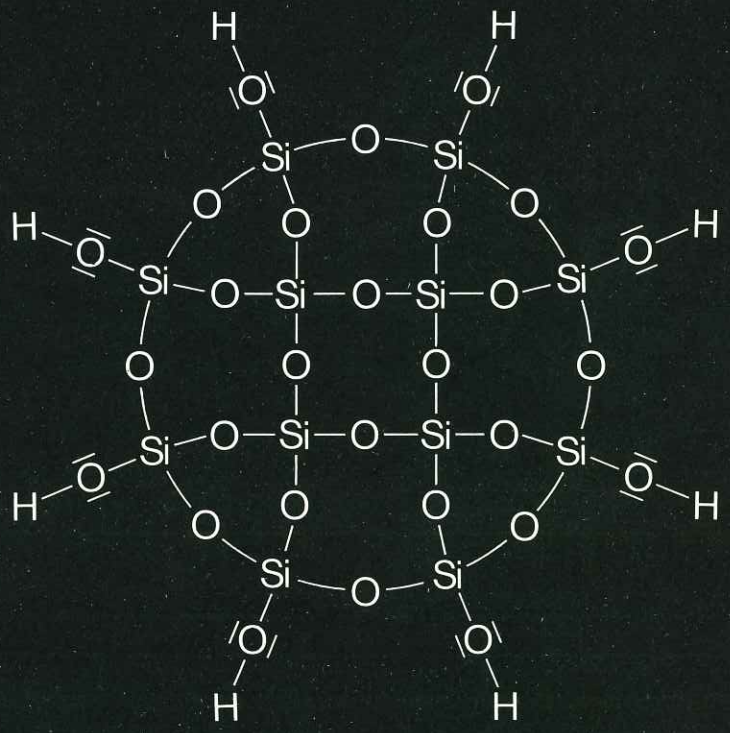


Light, fluffy, pure white Cab-O-Sil, piled on a laboratory micro-spatula.



Because of its low bulk density, Cab-O-Sil must be piled to overflowing on the pan to balance a ten gram weight.

Model of the type of lattice network which a sufficient concentration of Cab-O-Sil establishes when it is well dispersed in a liquid.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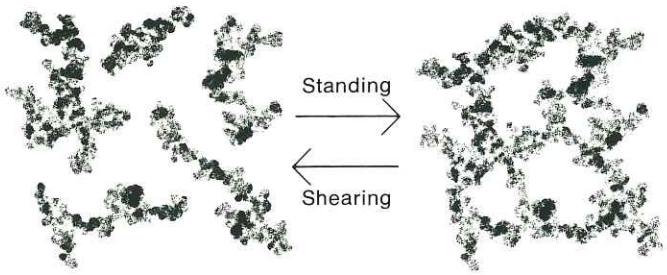
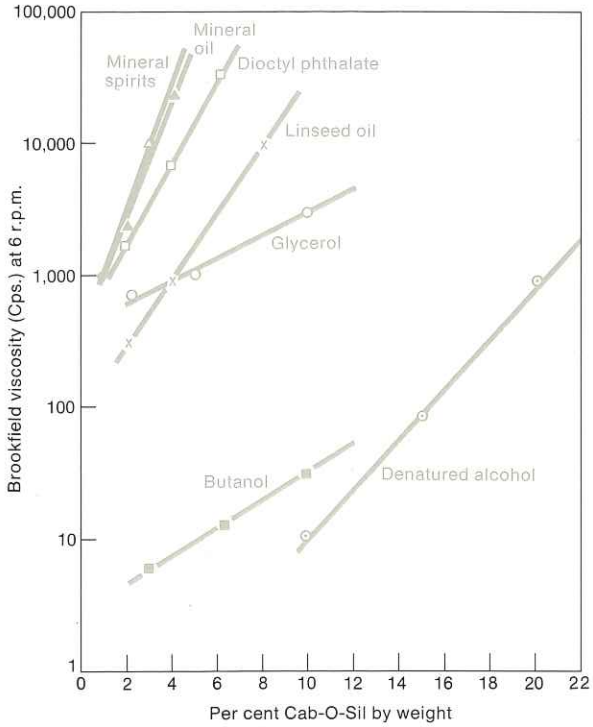
Cab-O-Sil's action in liquids

Most of the functions of Cab-O-Sil are brought about by the characteristic action of Cab-O-Sil once it is dispersed throughout any liquid system – its ability to develop a loosely-woven lattice-like network by hydrogen bonding between particles. This network is relatively stable when the system is at rest. Because its cohesive forces depend on a relatively weak hydrogen bond, however, it is easily disrupted through the action of an applied stress or shearing force, rebuilding itself when the shearing force is removed. This temporary disruption and subsequent rearrangement of structure is the key to many of the benefits provided by Cab-O-Sil.



In liquid systems at rest, Cab-O-Sil's characteristic lattice network forms as the Cab-O-Sil aggregates are drawn into contact by hydrogen bonding. Under shear stress, the relatively weak hydrogen bonds are broken and the structure reverts to individual Cab-O-Sil aggregates.



The polarity of a liquid determines the effect which a given concentration of Cab-O-Sil will have on its viscosity.

Cab-O-Sil for flow control

A number of terms are used to describe effects which are all basically related to flow control. Among them are: "anti-sag agent," "viscosity control agent," "bodying agent," "gellant," and "puffing agent." All pertain to thickening – which helps a coating to remain in a static, viscous layer without running down a surface or away from edges. When a Cab-O-Sil-containing coating comes to rest on a substrate, Cab-O-Sil's hydrogen-bonding characteristic causes it to form its three-dimensional network. This network physically restricts the internal flow of the coating, increasing its viscosity markedly through the drying or curing phase.

When introduced primarily as a viscosity control agent, Cab-O-Sil is usually added at a level of 0.5% to 3.0% by weight of the total formulation. The amount to be specified in any given case is determined by (1) the viscosity required in the final product, and (2) the viscosity of the formulation without the addition of Cab-O-Sil. The degree to which Cab-O-Sil modifies flow properties is determined by the extent of network formation which occurs in the system. This, in turn, depends on a number of factors, the principal ones being the polarity of the liquid phase, the additives present, the concentration of Cab-O-Sil, and the degree of dispersion. Other factors are temperature, aging, the grade of Cab-O-Sil and pH (in the case of aqueous systems).

Viscosity and thixotropy will be greatest when network formation occurs, as in the non-polar system with good dispersion and the system where multifunctional polar molecules (sometimes called bridging compounds) are present in small concentration. Less than optimum yields of viscosity and thixotropy will be attained when Cab-O-Sil is either under-dispersed or over-dispersed.

The presence of additives can either promote or inhibit chain formation. In systems of low polarity, chain formation, with consequent development of viscosity and thixotropy, will be increased by the addition of a multifunctional polar bridging compound, e.g., ethylene glycol, glycerol, or a suitable wetting agent, in an amount in the range of 10% to 40% based on the weight of the Cab-O-Sil in the formulation. If it is desirable to decrease the viscosity of a Cab-O-Sil dispersion of low polarity, this can be accomplished by the addition of solvent or of a very small amount of a long chain mono-functional alcohol, amine or similar hydrogen-bonding compound. For a more complete discussion of additives and dispersion techniques, see the Cab-O-Sil general brochure.

When systems have been made with properly chosen solvents and additives and with good dispersion, temperature and aging do not affect Cab-O-Sil's efficiency markedly. In aqueous systems Cab-O-Sil exhibits maximum thickening efficiency at a pH of about 5.6. It is operable over a wide range, however, but with significantly less efficiency at very low and very high pH levels.

Cab-O-Sil's functions in coatings

Coating[1]	Anti-caking	Anti-sag	Edge Coverage	Emulsification	Fluidization	Free Flow	Gloss Reduction	Hold-out	Suspension[2]	Thickening[3]	Thixotropy[4]	
Acrylics		●	●				●		●	●	●	
Aerosols	●	●		●					●		●	
Alkyds		●					●	●	●	●	●	
Cellulosics		●	●						●	●	●	
Chemicals – Dry	●					●						
Elastomers							●		●	●	●	
Emulsions				●					●	●	●	
Epoxies		●					◑		●	●	●	
Lacquers		●					●		●	●	●	
Latexes		●						●	●	●	●	
Organosols		●	●						●	●	●	
Paints		●	●	●			●	●	●	●	●	
Phenolics		●	●							●	●	
Plastisols		●	●						●	●	●	
Polyamides		●	●							●	●	
Polyesters		●							●	●	●	
Polyethers		●	●							●	●	
Powder Coatings	●	●	●		●	●				●	●	
Resins – Dry	●				●	●						
Resins – Liquid		●					●	●		●	●	
Shellacs		●									●	
Silicones		●	●							●	●	
Urethanes		●					●		●	●	●	
Varnishes		●					●			●	●	
Vinyls		●					●		●	●	●	

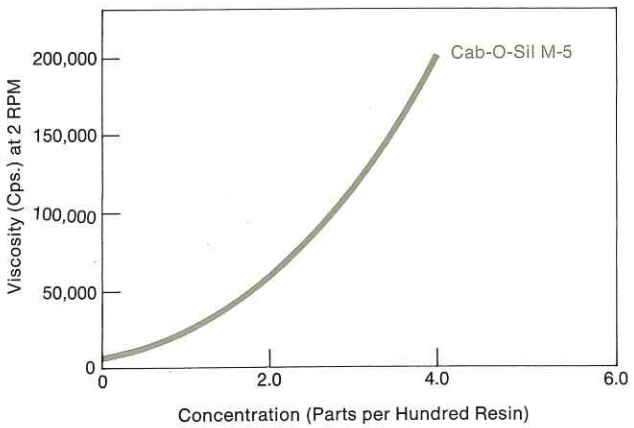
[1]*Coatings are liquid except where otherwise noted.*
[2]*Suspension of pigments or undissolved resins.*
[3]*Sometimes called Bodying.*
[4]*Sometimes called Puffing.*

Cab-O-Sil for thickening

Because small amounts of Cab-O-Sil are extremely efficient in producing high viscosity, the use of Cab-O-Sil eliminates the need to build up the total solids to high levels in order to produce a viscous, heavy-bodied coating. For example, in some polyester coatings and clear finishes the total solids are only 20% to 30% by weight, but sufficient viscosity is achieved by the use of Cab-O-Sil at a level of only 1% to 3% of the total formula. The smaller percentages of Cab-O-Sil needed also require shorter mixing times.

Furthermore, because of the greater thickening effect per unit of weight, Cab-O-Sil can be used to produce higher viscosities than are possible with many other thickeners. Manufacturers of vinyl coatings for structural steel and "high-build" epoxy coatings for the hulls of ocean-going vessels have used Cab-O-Sil as a way of achieving the high viscosities which make possible unusually heavy layers in one application. Even in thick finishes like these – where the total solids run 60% to 70% or higher – the level of Cab-O-Sil required for the necessary increase in viscosity is often only 2% to 3% of the total weight of the formula. In clear alkyd varnishes and pigmented semi-gloss finishes, with solids ranging from 60% to 70%, the use of 0.5% to 2.5% of Cab-O-Sil based on total formula weight is sufficient to give a "puffy body" to the coatings.

Cab-O-Sil offers an additional advantage – it does not impair the adhesion of a coating to the substrate to which it is applied. Vinyl plastisols thickened with Cab-O-Sil are used as coatings on glass bottles for increased impact resistance and to prevent particles of glass from scattering if breakage occurs. A manufacturer of epoxy coatings which impart strength to television picture tubes found that when Cab-O-Sil was used to replace other thickeners, the tendency of the cured coating to peel away from the glass was eliminated.



Efficient thickening is often achieved by Cab-O-Sil at much lower concentrations than those required by other types of thickeners. The curves shown are taken from a study of a typical vinyl plastisol.

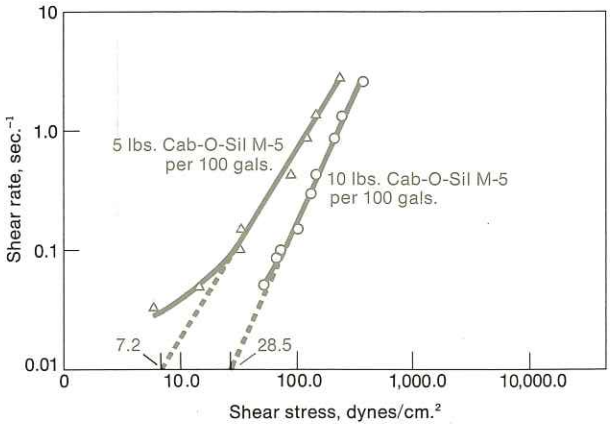
Cab-O-Sil for thixotropy

Thixotropy is a term used to describe the rheological behavior of certain liquid systems which display a decrease in apparent viscosity as shearing force is applied over a period of time or is increased in intensity. This behavior is imparted or enhanced by the addition of Cab-O-Sil to liquids. Whether coatings are applied by brushing, rolling, spraying, dipping, troweling or any other method, it is often desirable at some point that they flow freely under even the slightest driving force. Yet once they are on the substrate, they must have the viscosity needed to hold firmly and smoothly without running or sagging. Thixotropy in coatings allows the application of thick films which resist sagging and excessive penetration into small surface imperfections. The reduced penetration, sometimes called "hold-out," results in improved coverage and in some cases may reduce the number of coats required.

When Cab-O-Sil is included in the coatings, increased viscosity is produced in the static state as a result of hydrogen bonding. In the dynamic state, under the application of shear, a portion of the weak hydrogen bonds will be ruptured, causing a decrease in apparent viscosity. The number of bonds broken, and the consequent lowering of apparent viscosity, will increase as the shear force is increased. This can be demonstrated by measuring the coating viscosity with a Brookfield viscometer[1] and noting the decrease in viscosity reading as the speed, *i.e.*, shearing force, of the spindle is increased. Conversely, as soon as the shearing force is diminished or ceased, the hydrogen bonds begin to re-establish themselves and the viscosity approaches the initial static value.

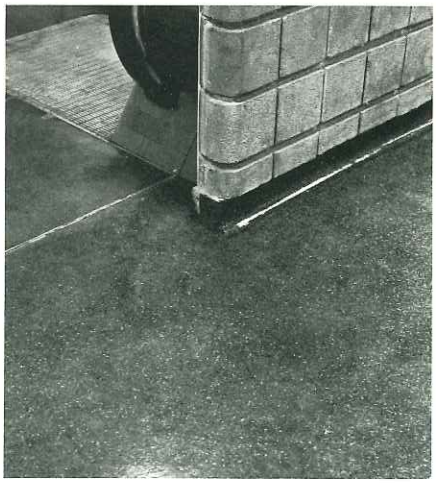
One laboratory method of measuring the degree of lattice structure within a liquid system is to determine its yield value. This is the stress required to cause the resting system to start flowing. A typical yield value determination is shown in the accompanying graph. Instruments

[1]*Brookfield Engineering Laboratories, Inc., 240 Cushing St., Stoughton, Mass. 02072.*



The yield point values of an alkyd semi-gloss paint made thixotropic by additions of Cab-O-Sil are determined by extrapolating the shear rate *vs.* shear stress curves to a shear rate value of 0.01 secs.$^{-1}$.

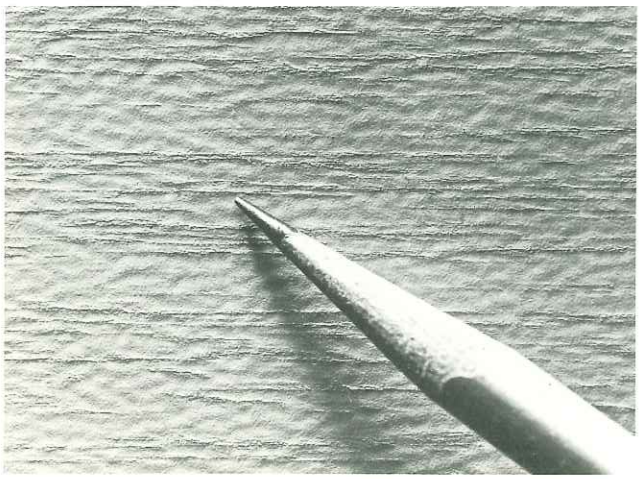
Worker at Minneford's Yacht Yard, City Island, N.Y. smooths epoxy fairing putty on bow of the Cup yacht *Courageous.* Putty is applied over white epoxy primer-barrier coating which protects aluminum hull from corrosion in salt water. Primer-barrier coating, produced by International Paint Co., contains Cab-O-Sil to impart thixotropy for even, non-sag application.



The Montreal Forum, home of the Montreal Canadiens, has floors and cove bases of clear epoxy-terrazzo installed by Lagendyk & Co., Ltd., Montreal, Canada. Thixotropy, thickness and suspension of the pebble agglomerates in the transparent matrix were all achieved by the addition of Cab-O-Sil at levels of 3% to 6% by weight.

Impact resistant glass bottles are coated by GET Plastics, Inc., St. Louis, Mo., with PVC plastisol manufactured by Dennis Chemical Co., St. Louis. Cab-O-Sil in the formulation promotes thick coatings with a single dip while preventing runs and sags.

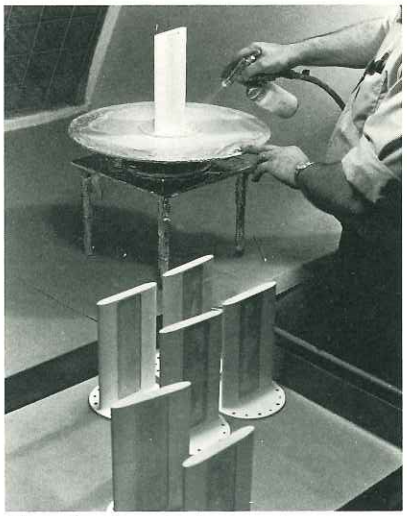
"Urabond" polyurethane roof and deck coating by Poly Resins, Sun Valley, Cal., is shown being applied on a combined roof and sun deck. Optimum spreading consistency is produced by the thixotropic and thickening functions of Cab-O-Sil.



Aluminum siding by Aluminum Industries, Inc., St. Louis, Mo., has a raised grain produced by a modified rotogravure process which uses for "ink" a vinyl plastisol coating manufactured by Dennis Chemical Co., St. Louis. The thixotropy produced by Cab-O-Sil allows trouble-free distribution of the coating, but maintains the shape of the ridges in the grain through the curing process.

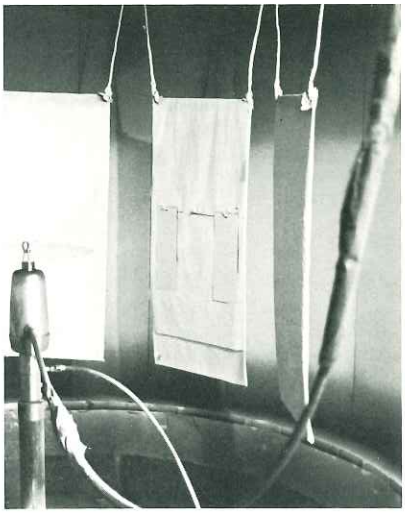
Poxolon epoxy swimming pool paint, manufactured by Kelley Technical Coatings, Inc., Louisville, Ky., contains Cab-O-Sil as a gelling agent. As an additional benefit, Cab-O-Sil improves film strength by structurally increasing the molecular cohesion.

In Sherwin-Williams' well-known Kem-Glo enamel, Cab-O-Sil helps sag control and contributes to lower gloss without affecting flexibility.



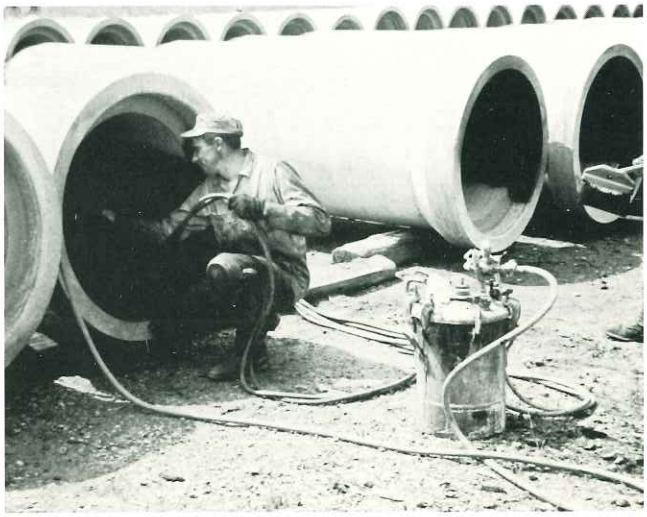
Aircraft external antenna units are spray-coated at Adams-Russell Co., Inc., Waltham, Mass., with epoxidized protective coating by Premium Finishes, Inc., Cincinnati, Ohio. Cab-O-Sil gives flow control and acts as a bodying agent.

Epoxidized PVC lacquer made by Premium Finishes, Inc., Cincinnati, Ohio, is applied to metal refuse containers with conventional air-atomized spray. Cab-O-Sil is used for bodying and flatting. (Photo courtesy Industrial Finishing Mag.)



Automatic electrostatic spray booth for testing liquid coatings at Reliance Universal, Inc., Louisville, Ky. Cab-O-Sil is added to the coatings for thickness and thixotropy, and to provide uniform suspension of pigments.

Production scale fluidizing bed manufactured by Armstrong Products Co., Inc., Warsaw, Ind. Cab-O-Sil is recommended for anti-caking and improved fluidization.



Concrete pipe interiors are protected from the acidity of decomposing sewage by INDURON high-build epoxy coating, Indurall Coatings, Inc., Birmingham, Ala. Airless spray is used to apply single-coat thickness of 10 to 12 mils. Viscosity and thixotropy control are supplied by Cab-O-Sil.

capable of measuring stresses at extremely low rates of shear – for example, the Rotovisco rotating viscometer[2] – are required for the determination of yield values.

The thixotropy of a system is proportional to the area enclosed between the two curves representing viscometer readings taken at increasing and decreasing rates of shear. The graph illustrates the degree of thixotropy imparted to an alkyd paint by Cab-O-Sil M-5. The hysteresis lag in returning to initial static viscosity is a major determinant of rheological performance during application of a coating. The goal in formulating coatings is to make this time period long enough to allow leveling, but short enough to prevent sagging.

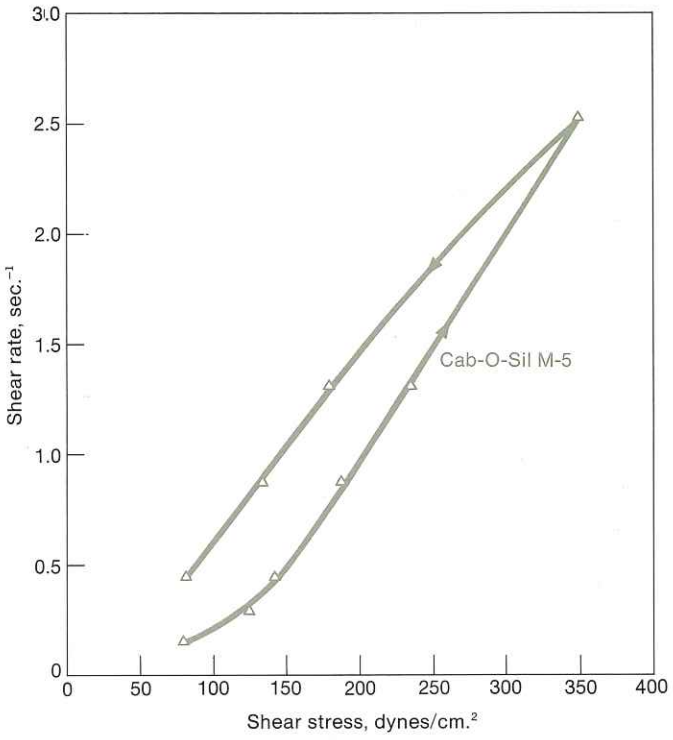
Good thixotropic properties can be produced in most coating systems by the use of 1% to 2% Cab-O-Sil by weight of the total formula.

For example, a manufacturer of epoxy paints designed for industrial coatings on heavy duty washing machines, sewage disposal units and similar appliances finds that the use of Cab-O-Sil at 1% of a formula containing 40% to 60% total solids gives good spray characteristics. As other examples, the same amount, 1% by weight, is used by some producers of vinyl insulation coatings for electrical appliances, applied by specialized automatic equipment, as well as by a maker of high-build epoxies applied with airless sprays.

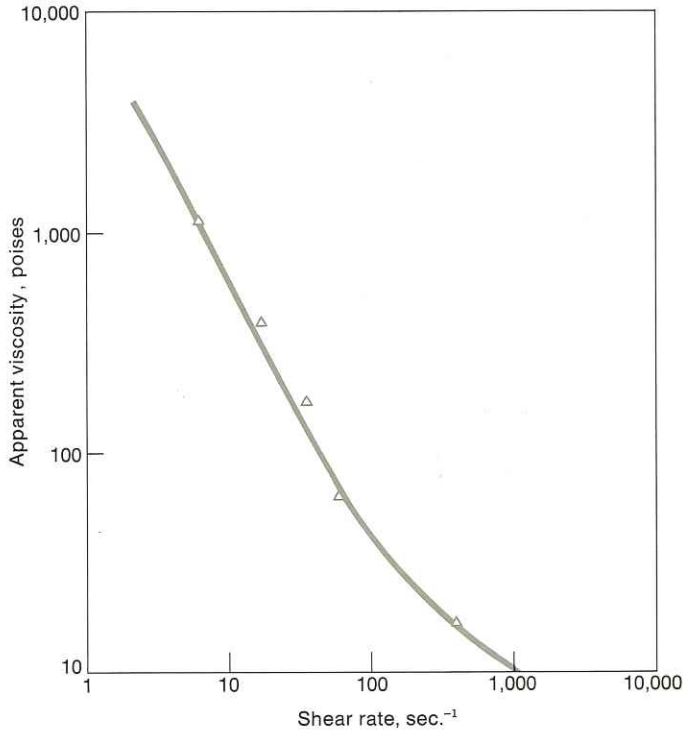
Shellac primer-sealers, at approximately 53% total solids, containing Cab-O-Sil at 1.25% of the total formula, retain desirable penetration characteristics while providing good coverage of edges, corners and projections. In a specialized line of opaque alkyd semi-gloss finishes with 60% to 70% total solids, the addition of 2.5% to 3.0% Cab-O-Sil gives good non-drip and spreading qualities and imparts a puffy body to the coating. Thixotropic properties have been developed in vinyl organosols used for coating metal furniture and equipment at levels as low as 0.1% to 0.2% of the total formulation. A firm producing two-component epoxy systems, 80% total solids – which are applied to the insides of storage tanks, tank cars and tank ships by spray or roller – adds 2% Cab-O-Sil to get the desired level of thixotropy.

In two-part epoxy systems, the type of hardener used can affect the level of viscosity and thixotropy achieved. Primary amine hardeners can be used without reduction of these properties. Polyamide hardeners, however, will cause loss of viscosity and thixotropy unless measures are taken to circumvent this condition. This viscosity loss can be prevented easily by simply adding Cab-O-Sil with or without an additive (for example, ethylene glycol at 1% to 8% of the weight of Cab-O-Sil) to the hardener portion of the formula. They should be added at the same concentration and in the same manner as they are used in the resin portion.

[2]*Brinkmann Instruments, Inc., Cantiague Road, Westbury, N.Y. 11590.*



Hysteresis envelope of alkyd paint containing Cab-O-Sil. Increasing and decreasing shear rates are indicated by the direction of the arrows. On standing, the final shear rate value gradually returns to the initial value.



Apparent viscosity *vs.* shear rate in an alkyd flat enamel containing 0.8% Cab-O-Sil by weight.

Cab-O-Sil for suspension

An important use of Cab-O-Sil in coatings is as a suspension aid – sometimes called an "anti-settling" agent. The suspending action of Cab-O-Sil is the result of three distinct properties or functions.

First, the extremely small particle size makes it unlikely that Cab-O-Sil itself will settle out of a liquid, once it is properly dispersed.

Second, Cab-O-Sil thickens a system, and any increase in the viscosity of a system reduces the probability that suspended particles will settle.

Third, the lattice network of Cab-O-Sil in a liquid mixture tends to keep the pigment or other suspended solid particles isolated from each other. Thus agglomeration into units large enough to separate from the suspending liquid is minimized. Cab-O-Sil's extremely small particle size and its very large surface area result in such a finely spaced three-dimensional network that even the smallest particles of pigment find themselves separated from each other. This structure is not completely broken even when shear forces are applied, because the chains tend to slide over each other, with hydrogen bonds shifting and re-forming rapidly. The presence of this partial or fragmented lattice results in improved shelf life for the paint.

In the event of pigment-vehicle separation, the presence of Cab-O-Sil prevents the formation of a hard cake. While some settling might occur during extended shelf storage, uniform dispersion is easily restored by simple rolling or shaking, as with paint store equipment, or even by hand stirring.

The suspending ability of Cab-O-Sil is a function of the degree of chain formation in the system. Therefore, suspension is modified by polarity, additives and dispersion in much the same manner as flow control properties are. Stable suspensions of solids in liquids and of liquids in liquids (emulsions) depend on the proper choice of suspending liquid, optimum dispersion method and degree, and the use of additives if necessary.

The amount of Cab-O-Sil required for adequate suspension depends on the total solids in the system and on the fineness and density of the particles. Usually, 1% to 2% of the total formula by weight is sufficient. When used for this purpose, Cab-O-Sil ordinarily is treated as a pigment, and can be put through sand mills, pebble mills, high speed disc agitators or other equipment together with the other pigments in the formula.

For highly viscous materials, such as 100% epoxy resin systems for floor surfaces which are applied with a trowel, the level of Cab-O-Sil is usually 3% to 4%. For vertical surfaces such as baseboards and walls, where sand or pebble agglomerates must be held firm without slipping downward, levels up to 6% by weight are effective. A side-benefit discovered by some users of Cab-O-Sil in epoxy matrices for flooring is that the aggregates are held slightly above the surface of the matrix so that a permanent non-slip feature is built into the floor. Cab-O-Sil has little or no effect on the transparency of epoxy systems, so the proper choice of pigments can create coatings in which the agglomerate seems to float in a clear, reflective, three-dimensional space.

In vinyl organosol systems where Cab-O-Sil provides pigment suspension, the level required is usually very low – on the order of 0.1% to 0.4% of the total formula. This is much less than the requirement for many other additives which have been used for the same purpose, and manufacturing procedures can be simplified because of the smaller amount of Cab-O-Sil involved. Cab-O-Sil can be blended in without the grinding which some other agents require.

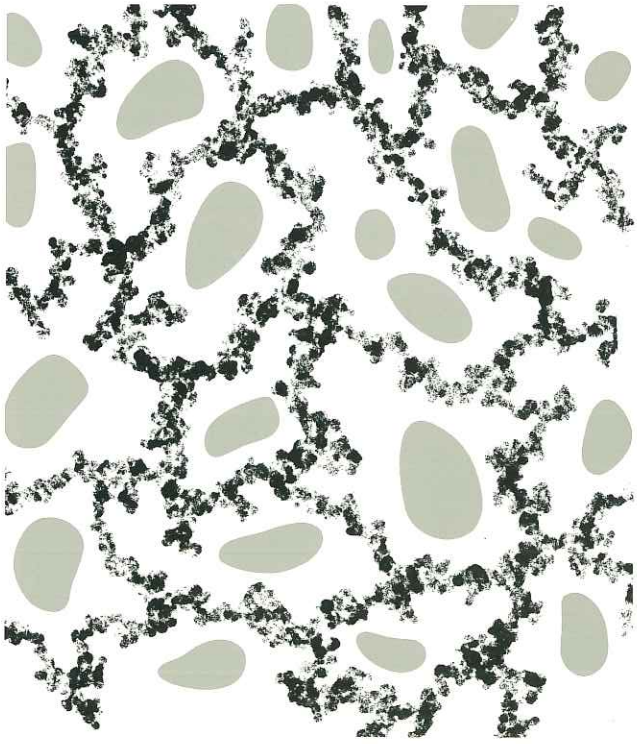


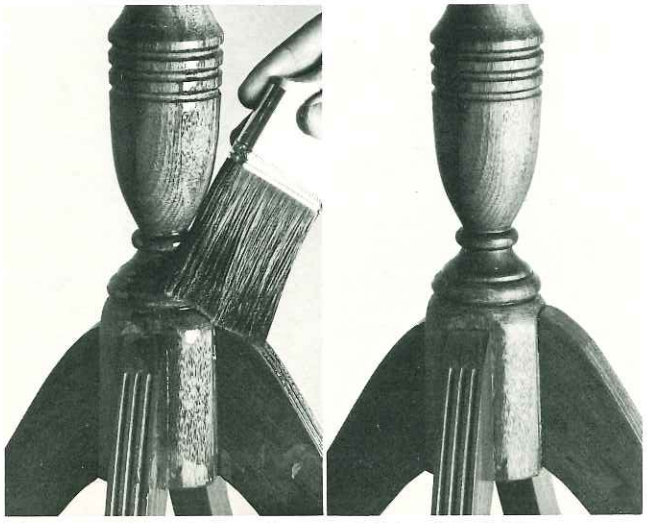
Diagram illustrating the suspending action of the Cab-O-Sil network. Particles of pigment or other undissolved solids are suspended in the lattice and prevented from coalescing with each other, which would produce phase separation.

Cab-O-Sil for gloss reduction

Gloss reduction, or flatting, is a property that can be imparted by Cab-O-Sil as a single specific objective – or as an additional benefit when the Cab-O-Sil is relied upon primarily for other functions. In clear lacquers, varnishes and shellacs Cab-O-Sil has the ability to reduce the sheen just enough to give a hand-rubbed look to the surface. The stability of the Cab-O-Sil lattice network makes this effect permanent. It is not marred by the subsequent hazing or development after drying of white areas that are sometimes associated with other additives which have been used to achieve a hand-rubbed appearance.

A moderate degree of gloss reduction can be produced by the use of 10% to 15% Cab-O-Sil by weight of the vehicle solids. For a complete flatting effect, higher levels up to 15% to 20% or more of the vehicle solids may be necessary. Where the additions of Cab-O-Sil are high, of course, the rest of the formula must be adjusted so that the viscosity does not exceed the desired level. For a discussion of additives which suppress or minimize the viscosity build-up of systems containing Cab-O-Sil, see the Cab-O-Sil general brochure.

When used for gloss reduction, Cab-O-Sil gives optimum effects at a Hegman Fineness of 5 to 6. Additional grinding beyond these readings is undesirable, for it results in a loss of the flatting effect. If a high speed disc stirrer is used, the proper procedure is to grind to a Hegman reading of 3 to 3½, then filter the entire mixture through a fine filtering medium such as 200 mesh nylon screen. This produces a final product having an overall fineness of 5 to 6. If a ball mill or pebble mill is used, the grinding operation can be carried to a fineness of 5 to 6. Sand mills also can be used to give a fineness of 5 to 6 with proper adjustment of the rate of flow through the grinding medium.

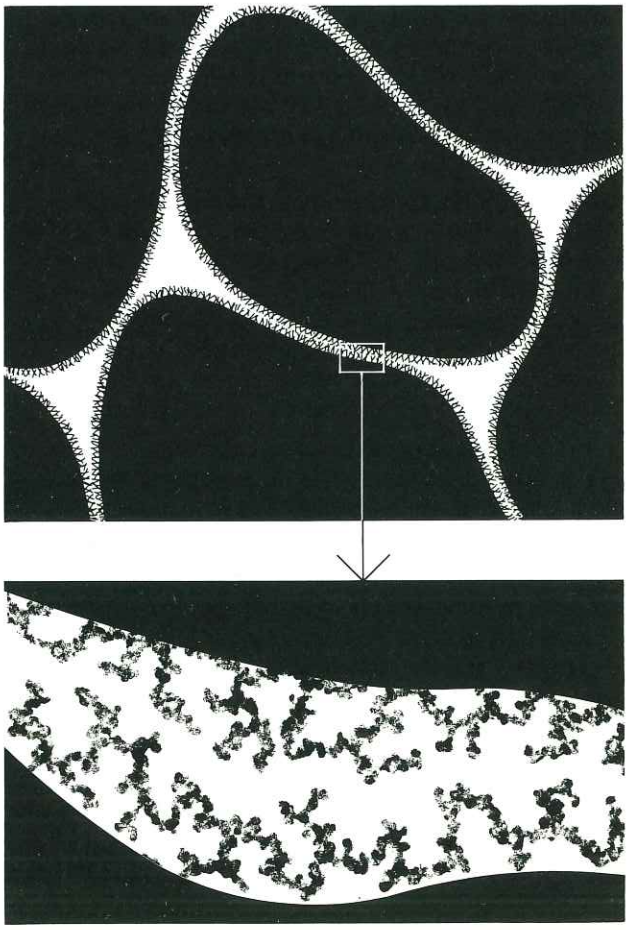


Clear, non-pigmented coatings containing Cab-O-Sil as a gloss reducing agent dry to a glowing hand-rubbed sheen.

Cab-O-Sil for free flow

In dry powders, Cab-O-Sil is extremely efficient in promoting free flow and preventing caking, clogging and bridging. It is able to perform these functions because its sub-microscopic particle size and tremendous surface area enable it to coat the powder particles effectively as a thin layer which acts as a surface of tiny "ball bearings". The amount required is very low in most cases, 0.1% to 1.0% by weight being usually sufficient.

Use as a free flow agent is common in powder coatings, dry pigments, and any other ingredients or formulations which are handled in the dry state.



Cab-O-Sil particles form a thin moveable layer on the larger particles of powdered materials with which they are mixed. Acting as tiny spacers they produce a ball-bearing effect, sliding and tumbling to promote free flow of the powder.

Cab-O-Sil in powder coatings

One of the most rapidly developing technologies in the coatings industry today is that of powder coatings. These are protective and decorative coatings which are applied entirely without the use of solvents or liquid carriers. Practically any polymer system can be used as the base for a powder coating. Among those which have been successfully used are vinyls, hydrocarbons, polyamides, chlorinated polyethers, cellulosics, epoxies, polyesters, acrylics, fluorocarbons, alkyds, phenolics and silicones.

There are many advantages which can be gained by coating with powders instead of liquids. Some of the more obvious benefits are the elimination of solvent evaporation into the atmosphere, the efficient use of almost 100% of the powder, the feasibility of building up very thick coats in one application, the possibility of using new materials not suitable for liquid dispersion and the reduction of drips, runs, sags, pinholes, and poor edge coverage.

Application methods are numerous, but the most common at present are 1) immersion in a fluidized bed and 2) electrostatic spray techniques. In the fluidized bed method, a pre-heated article is immersed in a bed of powder containing the base polymer, pigment and additives. The article must be pre-heated to a temperature above the fusing point of the powder, so that particles coming into contact with it will liquefy and adhere. The immersion is followed by a curing period at elevated temperature.

In the electrostatic spray method, the powder is given a static charge as it is discharged from a spray gun, while the article to be coated is charged oppositely. The coating is then held to the article electrostatically while the temperature is raised to the fusing and curing point. Work is being done on binders which will reduce or eliminate the need for high temperatures, so that the techniques may be applied to heat-sensitive items.

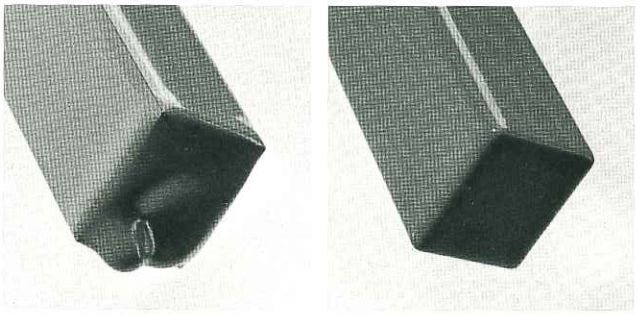
Cab-O-Sil has been used in powder coatings 1) to prevent caking, 2) to improve edge coverage and 3) to promote adhesion and cohesion. Added benefits which have been reported by users of Cab-O-Sil include reductions in sags, runs, pinholes, holidays and bridging.

A common problem encountered with powder coatings is their tendency to cake. This is particularly true in cases where beds of powder may be allowed to lie dormant for days or even weeks between periods of use. The addition of Cab-O-Sil to the powder will prevent hard caking, and will greatly facilitate fluidization when use is to be resumed. The usual level of usage for this purpose is 0.25% to 1.0% by weight.

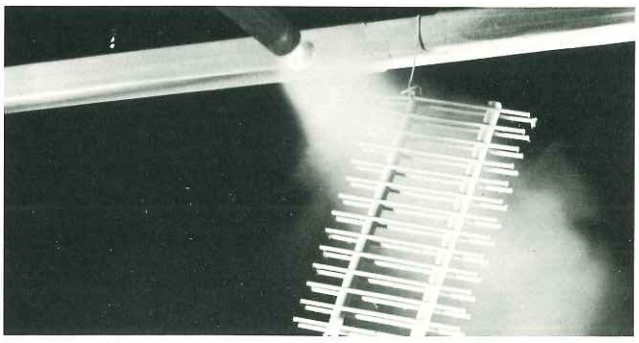
Another problem is that of edge coverage. Although initial coverage during immersion or spraying is usually uniform and satisfactory, many coatings tend to flow away from edges and corners during the fusing and curing steps. This is a surface tension effect, caused by the non-uniform directional cohesive forces exerted on the edge coating molecules by the coating molecules on the adjacent surfaces. Cab-O-Sil, being a heat-insensitive thickening and suspending agent, helps to give the coating on the edges and corners enough viscosity and stability to resist the forces which would otherwise make it flow toward these surfaces. Satisfactory levels of edge coverage can usually be achieved by the addition of Cab-O-Sil at levels of 1% to 3% by weight.

Adhesion to the surface on which the coating is applied, and stable uniform cohesion of the coating itself, are also properties which are greatly enhanced by the addition of Cab-O-Sil. This is brought about by the hydrogen-bonded network which Cab-O-Sil forms within the coating during the fusing step, when the coating is liquefied. Levels of Cab-O-Sil from 2% to 4% of the total formulation have been employed for adhesive and cohesive reinforcement. At the same time, sags, runs and drips are prevented by the flow control action of Cab-O-Sil, just as in the situations where it is used to eliminate the same faults in liquid coatings.

Although the field of powder coatings is relatively new, certain compositions have already been described in the patent literature. An example is the patent issued to Haag, U.S. 3,338,863 (Aug. 29, 1967), which covers certain epoxy formulations.



Tests of epoxy powder coatings with and without Cab-O-Sil at Armstrong Products Co., Inc., Warsaw, Ind. Cab-O-Sil (in coating on right) improves edge and corner coverage.



Electrostatic spray test of a polyester powder coating in the laboratories of Amoco Chemicals Corporation. Suggested formulations for coatings systems incorporating polymers based on Amoco's aromatic acids are routinely developed and tested. Cab-O-Sil is often recommended at levels of 1% to 2%.

Multiple functions with Cab-O-Sil

The use of Cab-O-Sil to achieve a specific function in a coating often results in some modifications or enhancement of other properties of the system as a whole. Usually these auxiliary improvements are welcome. Any analysis of the various properties sought will point the way to establishing the proper level of Cab-O-Sil to be used.

A general review of this section on coatings shows that in most cases the use of Cab-O-Sil somewhere in the range of 0.5% to 3.0% of the total formula will give optimum thickening, thixotropy and suspension. For maximum gloss reduction, higher concentrations of Cab-O-Sil must be used – 15% to 20% or more of the vehicle solids present. In many cases this will not cause excessive thickening. When it does, however, the viscosity can be reduced by the use of solvent or very small amounts of the proper additive.

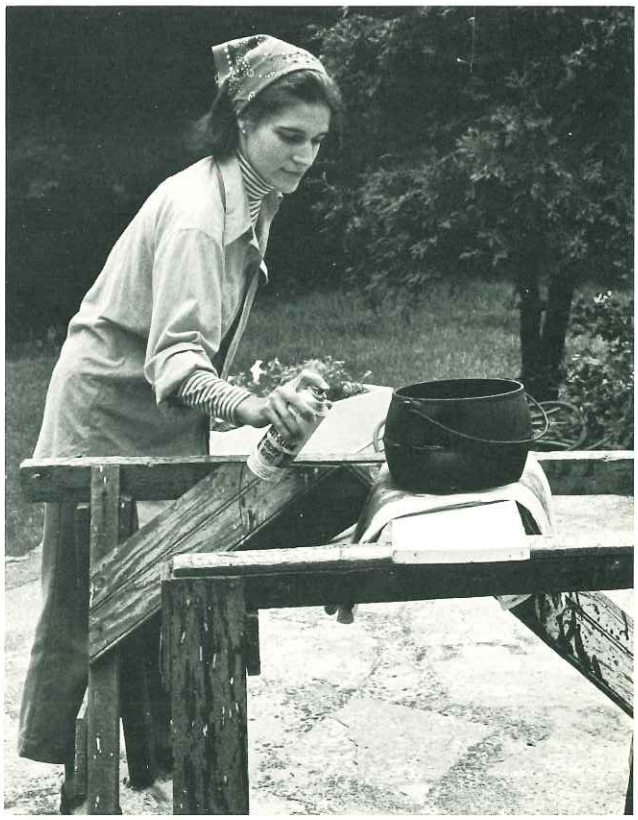
Cab-O-Sil has been instrumental in developing and improving coatings that include acrylics, alkyds, vinyls, epoxies, urethanes, polyesters, neoprenes, nitrocelluloses, varnishes, shellacs and latexes. On page 16 are presented some typical coatings formulas.

Cab-O-Sil in aerosols

A special case of suspension in which Cab-O-Sil is particularly useful is that of coatings packaged as aerosols. Here the contents must be maintained in a stable suspension so that the ingredients will be dispensed uniformly. Hard sedimentation in the can, or clogging of the dip tube or spray nozzle, destroys the usefulness of the product.

Cab-O-Sil's complete compatibility with organic solvents and propellants and its sub-microscopic particle size combine to make it the ideal suspending agent for aerosol products. Whereas other agents tend to cake and clog the nozzle, Cab-O-Sil maintains free flow throughout the system and promotes usefulness of the container until the contents have been completely evacuated. In many cases, the use of Cab-O-Sil eliminates the need for a ball inside the container. The thixotropy produced by Cab-O-Sil naturally helps to hold the aerosol products in place wherever they are sprayed, without running or sagging.

The levels used in aerosols are in the range of 1% to 2% of the active ingredients, which themselves are only 5% to 20% by weight of the total contents of the aerosol container.



Cab-O-Sil is used in aerosols to maintain solids in suspension and prevent hard settling and valve clogging. The thixotropy it provides also serves to eliminate runs and sags on the sprayed surface.

Getting the most from Cab-O-Sil

Optimum results from the use of Cab-O-Sil will be obtained by careful attention to the principal conditions of use. As discussed, the selection of proper additives can drastically reduce the amount of Cab-O-Sil needed. Also important is the selection of grade.

The grades of Cab-O-Sil commonly used in paints and other coatings are Cab-O-Sil M-5, Cab-O-Sil M-7, and Cab-O-Sil PTG-1. The properties of these grades are given in the accompanying tables.

Grade M-5, with a surface area of 200 $\pm$25m^2/gm, can be dispersed with any type of mill or any dispersing equipment of the high speed agitator type or similar stirrers, even those utilizing relatively low rates of shear.

Grade M-7 offers the advantage of greater density (4.0 $\pm$ 0.2 pounds/cubic foot), making it easier to handle. This grade is less readily dispersible in the liquid suspensions, and should be used only where dispersion is by mills or high shear mixing equipment.

Grade PTG-1 is designed primarily for use in polyester systems. The physical properties are the same as those of Grade M-5, but the thickening efficiency is higher. The energy requirement for efficient dispersion of this grade is intermediate between the amounts required for Grades M-5 and M-7.

Cab-O-Sil will function most efficiently when all its particles are distributed evenly throughout the system. Factors affecting dispersion efficiency are method of dispersion, the speed of the mixer, and the duration of the mixing cycle.

Some coatings manufacturers prefer to mix Cab-O-Sil as they would a pigment. In these cases it is ground in along with the pigment in sand mills, pebble mills, three-roll mills or other types of milling equipment.

Other producers consider Cab-O-Sil a separate additive, which is incorporated into the vehicle in a high speed disc agitator or similar shear equipment. This addition is usually followed by a short period of relatively slow stirring to accomplish wetting, then by high speed stirring to achieve good dispersion.

Cab-O-Sil is supplied in bags of ten, fifteen or twenty pounds, depending on the grade. The usual handling procedures involve simple manual opening and emptying of the bags. Various enclosed hopper arrangements and vacuum systems for transporting Cab-O-Sil have been devised for larger or more sophisticated operations.

The diagram on page 15 shows the physical structure of the Cab-O-Sil dispersion after various degrees of shearing action have been applied. Optimum dispersion can be recognized experimentally as the one having the highest apparent viscosity. When viscosity plateaus or decreases after additional shearing action, optimum dispersion has been passed and over-dispersion is being produced.

Physiological data

The FDA allows the use of Cab-O-Sil for certain functions and in certain concentrations in pharmaceuticals and foods. It is believed that Cab-O-Sil does not produce silicosis inasmuch as no case has ever been reported. As with any other fine powder, however, the use of dust masks by workers is encouraged as an ordinary safety precaution.

Cab-O-Sil is supplied in multiwall bags, net weight 10 pounds, as in this case, or 15 or 20 pounds, depending on the grade.

Right: The intensity and time duration of dispersion determine the degree of lattice formation by Cab-O-Sil in a liquid system. Good dispersion results in a loose network structure. Over-dispersion results in excessive breakage and scattering of the chain-like aggregates, inhibits their linking together and prevents the formation of the desired lattice.

Tested quality control standards.

	M-5	M-7	MS-7	M-7D	PTG-1[2]	MS-75	H-5	HS-5	EH-5	S-17
Surface Area (m^2/gm)[1]	200 ±25	200 ±25	200 ±25	200 ±25	200 ±25	255 ±15	325 ±25	325 ±25	390 ±40	400 ±20
Density ($lbs./ft^3$)	2.3	4.0 ±0.2	4.5 ±0.5	6.0 min.	2.3	4.5 ±0.5	2.3	2.3	2.3	4.5 ±0.5
pH (4% in H_2O)	3.5-4.2	3.5-4.2	3.6-4.2	3.5-4.2	3.5-4.2	3.6-4.2	3.5-4.2	3.6-4.1	3.5-4.2	3.6-4.0
All grades: 325 Mesh residue = 0.02% max.										

Values and ranges are those obtained on freshly-manufactured representative samples.

[1]*BET Method. See section on Properties.*

[2]*PTG-1 has physical properties similar to those of M-5, but has a higher thickening efficiency.*

Typical properties of Cab-O-Sil grades.

	M-5	M-7	MS-7	M-7D	PTG-1[2]	MS-75	H-5	HS-5	EH-5	S-17
Nominal Particle Size (Diameter in Microns)[1]	0.014	0.014	0.014	0.014	0.014	0.011	0.008	0.008	0.007	0.007
Ignition loss (1000°C. moisture-free basis.)	1.0%	1.0%	1.0%	1.0%	1.0%	1.5%	2.0%	2.0%	2.5%	2.5%
Bag Weight (lbs.) (Net)	10	20	20	20	10	20	10	10	10	20

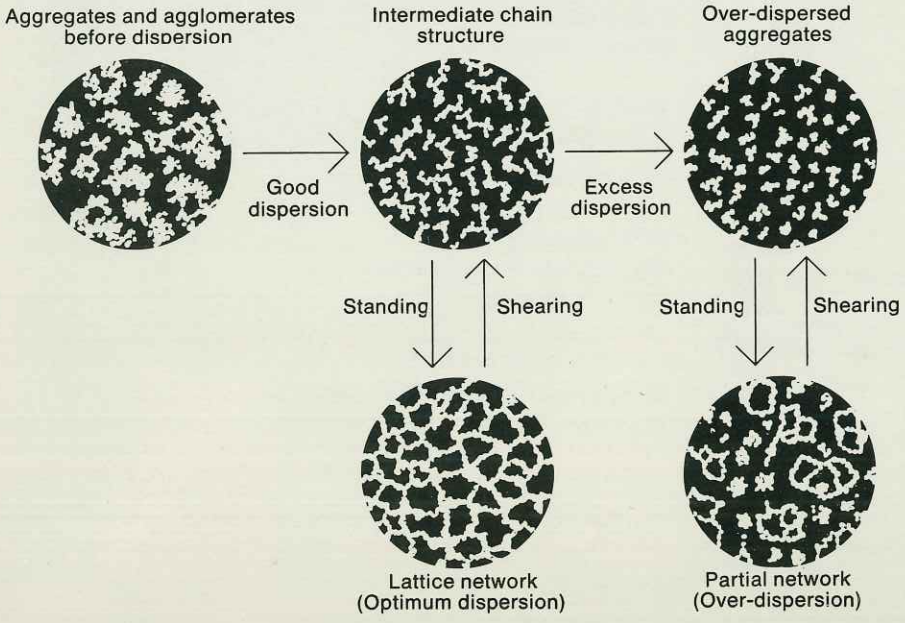
All grades: Bulking Value = 5.5 gal./100 lbs.
Specific Gravity = 2.2
Color = White
Silica Content = 99.8%
Refractive Index = 1.46
X-ray Form = Amorphous

These figures represent average values obtained, but are not to be construed as rigid quality control standards.

[1]*Calculated from the surface areas (BET Method) assuming sphericity of particles.*

[2]*PTG-1 has physical properties similar to those of M-5, but has a higher thickening efficiency.*

Typical dispersion patterns of Cab-O-Sil.



Typical coatings formulas

High-build Epoxy Coating

Part A. (Hardener)	Pounds
Versamid 140 (General Mills)	210
Titanium Dioxide, Enamel Grade (O.A. 19-22)	500
Zinc Oxide	130
Xylol	89
Cab-O-Sil M-5	10
Glycerine	2
Butanol	59
	1000
Part B. (Epoxy)	
Epoxy Resin	810
Xylol	149
Urea-formaldehyde Resin*	29
Cab-O-Sil M-5	10
Glycerine	2
	1000

To use, mix Part A and Part B in 1:1 proportions.

*For example, Beetle 216-8 (60% Non-volatile), American Cyanamid.

White Alkyd Semi-gloss Enamel

A. Mill Base	Pounds (to make 100 gallons)
Phthalic Alkyd Resin (Duraplex D65A, Rohm & Haas)	200
Soya Lecithin (Kelecin FB, Spencer Kellog & Sons, Inc.)	5
Calcium Carbonate (Snowflake, Thompson, Weinman & Co.)	442
Titanium Dioxide, Enamel Grade (O.A. 19-22)	225
Cab-O-Sil M-5	10
Mineral Spirits	25
	907

The mill base was ground with a three-roll mill to a fineness of 5 to 5½ on the N.S. gauge.

B. Let-down	
Phthalic Alkyd Resin	125
Mineral Spirits	175
24% Lead Naphthenate	5
6% Cobalt Naphthenate	2.5
4% Calcium Naphthenate	5.5
Exkin #2 (Nuodex)	1
	1221.0

Viscosity (Kreb units): 76
60° Gloss on black Carrara glass: 28

Alkyd Undercoat Paint

	Parts by weight
Mixed Alkyds	24.20
Titanium Dioxide, Enamel Grade (O.A. 19-22)	6.67
Atomite (Thompson, Weinman & Co.)	46.87
ASP 400 (Minerals & Chemicals Corp.)	6.80
Cab-O-Sil M-5	0.31
Alcohol	0.08
Odorless Mineral Spirits	14.27
6% Cobalt Naphthenate	0.20
24% Lead Naphthenate	0.50
Methyl Ethyl Ketoxime Anti-skin	0.10
	100.00

Viscosity (Kreb units): 94

Zinc Rich Primer

	Parts by weight	Parts by volume
Cellosolve Silicate X-8018 (Union Carbide)	37.65	80.14
Cab-O-Sil M-5	0.68	0.69
Trimethyl Borate	0.68	1.64
Zinc Dust Z-111 (American Smelting and Refining)	60.99	17.53
	100.00	100.00

Make dispersion of first three ingredients, then blend in zinc dust with agitation. Cure at 50% relative humidity or higher, 40°F. or higher. Allow 8 hours to 48 hours for hardening.

Pot life 8 hours.

Semi-gloss Polyurethane Varnish – Mill Base Grind

	Pounds	Gallons
A. Mill Base		
Polyurethane 101 (Cargill, Inc.)	127.5	16.9
Cab-O-Sil M-7	33.3	1.8
Mineral Spirits	187.0	28.5
	347.8	47.2

This base was ground in a pebble mill to a fineness of 5½ on the N.S. gauge.

B. Let-down		
Polyurethane 101	318.0	42.7
Mineral Spirits	66.5	10.1
6% Cobalt Naphthenate	1.12	0.14
6% Manganese Naphthenate	1.12	0.14
24% Lead Naphthenate	3.36	0.39
	737.90	100.67

60° Gloss on black Carrara glass: 45

Semi-gloss Alkyd Varnish – Full Formulation Grind

	Pounds	Gallons
A. Mill Charge		
Alkyd (50% Non-volatile)	517.0	69.5
Cab-O-Sil M-7	38.8	2.2
Solvent (Mineral Spirits)	187.0	28.4
	742.8	100.1

The mill charge was ground to a fineness of 5½ on the N.S. scale in a pebble mill and discharged.

B. Driers and Anti-skinning Agent		
6% Cobalt Naphthenate	0.26	0.03
24% Lead Naphthenate	1.29	0.15
4% Calcium Naphthenate	0.26	0.03
Exkin #1 (Nuodex)	2.60	0.31
	747.21	100.62

Viscosity (Kreb units): 54
60° Gloss on black Carrara glass: 35

Index

Acrylic	5, 12
Additives	4, 9, 10, 11, 13, 14
Aerosols	5, 13
Aging	4
Agitators	10, 14
Alcohol	4
Alkyds	5, 6, 9, 13, 16
Amine	4, 9
Anti-caking	2, 5, 12, 13
Anti-sag	4, 5, 12, 13
Anti-settling	2, 10
Bodying agent	4, 5
Bridging compounds	4
Calcium	2
Cellulosics	5, 12
Chloride	2
Dispersion	4, 10, 12, 14, 15
Edge coverage	5, 9, 12
Electrostatic spray	12
Emulsions	5, 10
Enamel	16
Epoxy	5, 6, 9, 10, 12, 13, 16
Ethylene glycol	4, 9
FDA	14
Flatting	11
Fluidization	2, 5, 12
Fluorocarbons	12
Foods	14
Free flow	2, 5, 11
Gellant	4
Gloss reduction	2, 5, 11, 13
Glycerol	4
Grades	2, 4, 14, 15
Grinding	11, 14
Hardener	9
Hegman N.S. gauge	11, 16
Hold-out	5, 6
Hydrocarbons	12
Hydrogen bonding	2, 3, 4, 6, 10, 12
Hydroxyl	2, 3
Lacquers	5, 11
Latex	5, 13
Magnesium	2
Mills	10, 11, 14, 16
N.S. gauge	16
Neoprene	13
Nitrocellulose	13
Organosols	5, 9, 10
Penetration	6, 9
pH	4, 15
Pharmaceuticals	14
Phenolics	5, 12
Plastisols	5, 6
Polarity	4, 10
Polyamide	5, 9, 12
Polyester	5, 6, 12, 14
Polyether	5, 12
Polymer	2, 12
Powder	2, 5, 12
Puffing agent	4, 5
Puffy body	5, 6, 9
Resin	2, 5, 9, 10, 16
Safety	14
Shellac	5, 9, 11, 13
Silicones	5, 12
Silicosis	14
Sodium	2
Suspension	2, 5, 10, 12, 13
Temperature	4
Thickening	2, 4, 5, 6, 7, 10, 12, 13
Thixotropy	2, 4, 5, 6, 7, 9, 13
Urethane	5, 13, 16
Varnish	5, 11, 13, 16
Vinyl	5, 6, 7, 9, 10, 12, 13
Wetting agents	4
Yield value	6, 9

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125 High Street, Boston, Massachusetts 02110 (617) 423-6000

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